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THE COMPARISON OF USED TEMPLE OIL BIODIESEL PRODUCTIVITIES WITH THE OTHER BIODIESEL

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ABSTRACT

The present world is facing two serious problems, one global warming on account of environmental pollution and the other scarcity of fossil fuel. This has pointed to search alternative and sustainable energy sources which are renewable, cleaner and echo friendly. Edible, Non-Edible and waste cooking oils are viewed as promising renewable fuel sources, but their production cost is very high. Another major oil source in India is temple, where people pour oil over the idols like maruti and shani god, due to various mythological and religious beliefs. This huge mass collection of oil cannot be reused and is a waste. Therefore, this Used Temple Oil (UTO) could be an alternative source of energy.

This paper mainly focuses on the comparison of the methods of biodiesel production, catalyst used and their relative merits and demerits. It compares the properties of different oils and their respective biodiesel. It compares the fatty acid analysis of different biodiesel with Used Temple Oil Methyl Ester (UTOME). It throws light on the cost analysis of UTOME. Finally, it highlights the emission characteristics of different biodiesel in comparison with UTOME.

KEYWORDS: Environment, Sustainable, Renewable, Biodiesel & Used Temple Oil

Original Article

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INTRODUCTION

In today's world the most important resource for mankind is energy and also it plays a significant role in sustainable development of mankind. Now a day the crisis of energy confronting us because it has become one of global issue [1]. Fuels are burnt to produce large amounts of energy, hence they are very important to us. Day by day the use of diesel fuel is increasing. Thus, many inventions have become more attractive to find for alternative fuels to substitute fossil fuels. From edible, non edible and waste cooking oil or animal oil can be regarded as an alternative diesel fuel to produce biodiesel [2].

More than 350 oil bearing crops are identified for the production of biodiesel. Among all these few are typically considered as potential alternative fuel for diesel engine, such are soyabean, palm, sunflower, rapeseed and peanut. Mustard seed, Jatropa Curcas, cotton seed and calophyllum inophyllum vegetable oil plants are also under consideration for the production of biodiesel. All these vegetable oil got a significant importance due to their environmental benefits as well as its from renewable resources [3-5].

From edible oil, non edible oil, fats, waste cooking oil and algae the biodiesel can be derived. For the production of biodiesel use of virgin vegetable oil (edible oil) as a raw material is beneficial, because of its low

free fatty acid content. The main advantage of biodiesel synthesis over non edible oil source is due to their high free fatty acid content. For the production of biodiesel waste cooking oil can be used instead of using virgin vegetable oil as a raw material [6-8].

This paper mainly deals with the production, properties and emission of biodiesel from Used Temple Oil and also different types of oils. In India hundred of devotees pour vegetable oil over the idols of God like maruti and shani temples due to various mythological and religious, beliefs. The oil once poured cannot be reused and became waste. The production cost of biodiesel from non edible oil was higher than that of fossil fuels, due to higher cost of its raw material. This can be reduced (cost) by using Used Temple Oil as an alternative as feedstock.

Feedstock for Biodiesel

To convert oils and fats into biodiesel there are more important four ways. They are: pyrolysis (thermal cracking) micro emulsification, dilution and transestirification methods. Among all these 4 methods transesterification is considered as one of the best methods for the production of high quality of biodiesel [9-11]. Using WCO (waste cooking oil) as a raw material is attracting more attention and is becoming more alternative in biodiesel production via transesterification [12]. For the production of biodiesel fuel a number of methods are currently available and have been adopted. To produce biodiesel there are four primary ways shown in the Table 1.

Table 1: Different Methods of Biodiesel Production

Methods	Definition	Advantage	Disadvantage	Problems of using in Engines
Direct use and blending	Direct use as diesel fuel or blend with direct diesel fuel	Liquid nature portability Heat content (80 % of diesel fuel) Readily available, renewability	Higher viscosity Lower volatility Reactivity of unsaturated hydrocarbon chains	Coking and trumpet formation Carbon deposits Oil ring sticking Thickening and gelling of the lubricating oil
Micro emulsions	A colloidal equilibrium dispersion of optically isotropic fluid microstructures with dimensions generally in the 1-150mm range formed spontaneously from two immiscible liquids and one or more ionic or non –ionic amphiphiles	Better spray patterns during combustion Lower fuel viscosities	Lower cetane number	Irregular injector needle sticking, incomplete combustion Heavy carbon deposits, increase lubrication oil viscosity
Thermal cracking (pyrolysis)	The conversion of long chain and saturated substance (biomass basis) to biodiesel by means of heat	Chemically similar to petroleum derived gasoline and diesel fuel	Energy intensive and hence higher cost	
Transesterification	The reaction of a fat or oil with an alcohol in the presence of catalyst to form esters and glycerol	Renewability, higher cetane number, lower emissions, higher combustion efficiency	Disposal of by – product (glycerol and waste water)	

Data taken from Ref [13]

For the production of biodiesel transesterification is a commonly employed method. To reduce the viscosity of oil or fat, using acid or base catalyst is the presence of methanol or ethanol. Comparing to acid catalyst and enzyme catalyst

transesterification with alkali catalyst (KOH and NaOH) is more economical [2].

Various catalysts used for production of biodiesel from waste cooking oil through transestrification shown in the Table 2.

Table 2: Different types of Catalysts used for Production of Biodiesel

Methods	Catalyst	Advantages	Disadvantages
Alkali homogenous catlyst	1) NaOH 2) KOH 3)Sodium Methoxide 4)Potassium methoxde	1)Faster 2)Higher yield 3)Mild reaction 4) Low cost	1)Formation of soap 2) Difficult to separate it from the final product, water interferes with reaction
Alkali heterogeneous catalyst	CaO, CaTio, CaZrO, CaO-CeO_2, CaMnO3, Ca, Fe_2O_3, Al_2O_3/KI, ETS-10, zeolite, alumina/silica-supported K_2CO_3	1)Separation of catalyst from product is easy 2)Formation of soap is avoided 3)Less corrosive, less toxicity, less environmental problem	High methanol to oil ratio is required to reach the highest possible conversion
Acid homogenous	Concentrated H2SO4, sulfonic acid	1)Suitable for high free fatty acid feed stock 2)Yield is high	1)Slow reaction 2)Nedd extreme pressure and temperature conditions 3)Difficult to separate 4)More corrosive
Acid heterogeneous	ZnO/I2, ZrO=SO2, Sr/ZrO2 TiO2=SO2, carbon-based solid acid catalyst, carbohydrate-dervied catalyst, Vanadyl phosphate, niobic acid, sulphated zirconia, Amberlyst-15, Nafion-NR50	1)Less corrosive 2)Less toxicity 3)Less environmental problem	1)Low acid concentration 2) High cost 3) Diffusion limitation
Enzyme	Candida Antarctica fraction B lipase, Rhizomucor micher lipase, E aerogenes lipase, lipase immobilized on hydrotalcite and zeolites	1)Byproduct of process can be easily removed 2)Free fatty acid can be completely converted into methyl esters, regeneration and reuse of immobilized enzyme catalyst are possible	1)High reaction time required 2)Expansive, activity loss, agglomeration of enzyme

Data taken from Ref [14]

With a chemical structure of fatty acid alkyl esters biodiesel is a clean burning diesel fuel. For producing biodiesel various methods available. The most commonly adopted method is the alkali- catalysed transesterification of vegetable oils and animal fats. As a reactant and a catalyst the transesterification reaction require an alcohol. Methanol white sodium is the most commonly used alcohol and potassium hydroxide is the most commonly used catalyst. The molar ratio of alcohol to triglycerides should be increased to 6:1 with the use of an alkali catalyst to ensure a complete transesterification reaction. Depending on the oil used between 50^0C and 60^0C the optical temperature ranged. The most commonly used catalyst is the optimal condition of catalyst concentration is about 1.5 wt% for NaOH [13].

Via base catalyst transesterification process investigated characteristics of biodiesel produced from palm oil. Three important parameters were selected to find the optimum yield value of biodiesel. Such as reaction temperature 40, 50 and 60^0C, reaction time 40,60 and 80 mm and methoxide ratio 4:1,6:1 and 8:1. The optimum yield value 88% was

achieved by conducting the experiments by the parameters, such as reaction temperature 60^0C, reaction time 40 minutes and methoxide ratio 6:1 [15].

An approximate yield of 80% was observed for soybean and sunflower oils at methanol to oil ratio of 6:1. The conversions were almost same after 1 hour (93% - 98%) 40:1 is the effect of reaction time for palm oil, 5% with methanol oil. H_2SO_4 (v/v) at 95^0C for 9 hours and obtained a maximum yield of 97% [16]. For cotton seed oil the reaction temperature was studied the methanol to oil ratio of 6:1, catalyst concentration of 2% NaOH, reaction time of 90 min and agitation sepeed of 600 rpm, the maximum biodiesel was obtained at 60^0C [17].

Temperature, reactant ratio and catalyst concentration on the biodiesel yield were analysed 6:1 molar ratio of methanol to oil, 0.92% is the best combination of parameter. NaOH catalyst, the reaction temperature is 60^0 C and reaction time is 60 minutes. After transestirification and is comparable to diesel the viscosity of jatropa oil reduces substantially [18]. In this method NaOH or KOH were used as catalyst waste cooking methyl ester was heated up to 60^0CTable 3 Optimum conditions for biodiesel.

Table 3: Optimum Condition for Biodiesel

Methanol Oil Molar Ratio	Catalyst Type	Catalyst Content (wt%)	Reaction Temperature (^{0}C)	Reaction Time (hr)	Kinematic Viscosity at 40^{0}C	Biodiesel Yield (%)
7.5:1	KOH	0.5	60	0.5	4.3	94
6:1	NaOH	1	50	1.5	4.25	92
6:1	KOH	1	65	1	4.6	96

Data taken from Ref [19]

In the above Table 3, it is seen that the kinematic viscosity molar ratio 6:1 of NaOH catalyst is 4.25 is less than the other two values that is 4.3 and 4.6. But the biodiesel yield of molar ratio 6:1 of KOH catalyst is 96%.

The used temple oil is first filtered to remove solid impurities. It is preheated up to 50-60^0C to reduce the viscosity. The same oil is further heated up to 100ºC for half an hour to remove moisture. The basic catalyst (NaOH, 4.65 g/litre of oil) is dissolved in methanol (96 ml, 99.5% purity, density 0.791 g/cm³) in a separate vessel and is poured into a round bottom flask containing pre-heated oil (around 60ºC) while stirring the mixture continuously, with a magnetic stirrer for 2 hrs at 640 rpm to mix the oil with the sodium meth oxide properly. Once the reaction is complete, it is allowed for settling for 10-12 hrs in a separate funnel. The products formed during transesterification are used temple oil methyl ester and glycerine. The bottom layer consists of glycerine, excess alcohol, catalyst impurities and traces of un-reacted oil. The upper layer consists of clean amber coloured temple lamp oil methyl ester. After settling, the glycerol layer is removed. Esterifies oil washed with water. The washing is carried out in a separate funnel. The separated biodiesel is used for characterization. The biodiesel yield is 94.51% (at 1.15 of catalyst, molar ration 6:1, 95 min time at 60^0 C and 600 rpm) after purification.

Fatty Acid Analysis of Different Oils, Biodiesel and Utome

Petroleum diesel fuels having different hydrocarbon chains and contains sulphur, aromatic hydrocarbons and crude oil residue contaminants. But biodiesel not contain any sulphur, aromatic hydrocarbons, metals or crude oil residues. The hydrocarbon chains are generally 16-20 carbons in length and contains oxygen at one end, and it contains about 10% oxygen by weight, hence it has the poor oxidation stability [20]. The analysis of fatty acid value of different vegetable oils and Used Temple Oil is shown in the Table 4 and Table 5.

Table 4: The Analysis of Fatty Acid Values in the Vegetable Oils

Vegetable Oil	Fatty Acid Content %							
	Myristic 14:0	Plamitic 16:0	Palmitoleic Acid 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3	Arachidic 20:0
Safflower	0.30	7.3	0	1.9	13.6	72.3	0	0.3
Soybean	0	13.9	0.3	2.1	23.2	56.2	4.3	0.16
Sunflower	0.08	6.1	0.12	3.7	30.1	58.5	0.11	0.23
Canola	0	4.74	0.19	1.80	69.0	19.8	7.88	0
Corn	0.26	10.8	0.08	2.23	26.1	58.4	0.91	0.43
Olive	0.40	5.0	0.32	1.68	74.7	17.6	0	0.80
Hazelnut	0.1	5.2	0.3	2.1	78.0	13.8	0.3	0.1

Data taken from Ref [21]

Table 5: GC Analysis of Fatty Acid Values of Used Temple Oil

Vegetable Oil	Fatty Acid Content %							
	Myristic 14:0	Plamitic 16:0	Palmitoleic acid 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3	Arachidic 20:0
UTO	1.24	40.8	0.16	4.56	38.22	13.15	0.30	0

The observation clears that the Hazelnut, Olive and Canola oils contained higher percentage (78.0, 74.7, and 63.0% respectively) of oleic acid when compared to the other and the Safflower, Soybean, Sunflower and Corn oils contained higher percentage of linonleic acid 72.3%, 56.2%, 58.5% and 58.4% respectively. But the value of Palmitic, Oleic acid and Linoleic acid of Used Temple Oil are 40.8%, 38.22% and 13.15% respectively.

The analysis of the fatty acid value of different biodiesel and Used Temple Oil biodiesel is shown in Table 6 and Table 7.

Table 6: The Results of Fatty Acid of Biodiesels

Vegetable Oil	FAME Composition of Biodiesel %							
	Myristic 14:0	Plamitic 16:0	Palmitoleic acid 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3	Arachidic 20:0
Safflower	0.21	6.68	0	2.05	17.88	70.36	0.62	0.34
Soybean	0.18	0	11.07	4.08	23.70	51.84	7.32	0.37
Sunflower	0.32	6.67	0.17	3.65	28.64	57.63	0.48	0.23
Canola	0.23	5.46	0.32	1.98	61.64	19.27	7.76	0.29
Corn	0.15	14.33	0.19	1.92	28.26	53.07	0.21	0.21
Olive	0.10	6.90	0.43	2.20	57.93	19.25	6.84	0.42
Hazelnut	0.49	6.19	0.20	2.00	75.36	14.83	0.22	0

Data taken from Ref [21]

Table 7: The Results of Fatty Acid of Used Temple Oil Methyl Ester

Vegetable Oil	FAME Composition of Biodiesel %							
	Myristic 14:0	Plamitic 16:0	Palmitoleic acid 16:1	Stearic 18:0	Oleic 18:1	Linoleic 18:2	Linolenic 18:3	Arachidic 20:0
UTOME	0.89	30.49	0	2.39	35.88	26.36	0.76	0.27

In the above table the observation clears that comparing to other vegetable oil the Ccanola, Olive and Hazelnut biodiesel contained higher percentage of oleic acid are 61.64%, 57.93% and 75.36% respectively and Safflower, Soybean, Sunflower and Corn biodiesel contained linoleic acid are 70.36%,.51.84%, 57.63% and 53.07% respectively. But the

UTOME contained higher percentage of Palmitic and Oleic acid (30.49% and 35.88% respectively and also having 26.36% of Linolenic acid.

It has been shown that biodiesel fuel has lower thermal efficiency compared to high statured fatty acid composition. And biodiesel fuel with more unsaturated fatty acid composition has more density but has lower octane number, less viscosity and heating value. Also it emits lower HC and CO and compared to highly statured biodiesel fuel has less smoke. Constituting the dominant fatty acids the UTOME and UTO are saturated with oleic, linoleic and palmitic acid.

Fuel Properties of Different Oils, Biodiesels and Utome

The different physicochemical properties of diesel, other oils and Used Temple Oil are summarized in Table8.

Table 8: Physicochemical Properties of Diesel and other Oils

Oil	Calorific value (KJ/kg)	Kinematic Viscosity (mm^2/s) at 40^0 C	Flash point (^{0}C)	References
Diesel	42,232	3.21	76	22
Jatropha oil	39,584	38	235	22
Rice bran oil	41,100	38	184	23
Corn oil	38,300	44	310	23
Soya bean oil	39,579	31.739	-	
Palm oil	39,867	41.932	-	10
Calophyllum inophyllum oil	38,511	55.677	-	10
Aphanamixis polystachya oil	38,729	35.093	-	10
Canola oil	39,751	35.706	-	10
Used Temple oil	38,561	26.6	202	

In the above table the observation clears that the Calorific value of Rice bran oil (41,100 KJ/kg) is very nearer to the Diesel (42,232 KJ/kg) value. The Used temple oil Calorific value (38,561 KJ/kg) is higher than the calorific value of Corn oil (38,300 KJ/kg) and Calophyllum inophyllum oil (38,511KJ/kg) and also nearer to Jatropha oil (39,584 KJ/kg), Soya bean oil (39,579 KJ/kg) and Palm oil (39,867 KJ/kg). The flash point of Corn oil is 310^{0}C which is higher than other oils accepts diesel. The rice bran oil having 184^{0}C which is higher than diesel and lower than the other oils mentioned in the table. The used temple oil having a flash point 202^{0}C, it is also higher than the diesel and lower than other oils, but it is nearer to Rice bran oil (184^{0}C). The physical chemical properties of different biodiesel are shown in the Table 9.

Table 9: Physicochemical Properties of Different Biodiesels

Biodiesel	Calorific Value (KJ/kg)	Kinematic Viscosity (mm^2/s) at 40^0 C	Flash Point (^{0}C)	References
Jatropha biodiesel	39,594	4.12	162	22
Rice bran methyl etser	41,300	4.54	162.8	23
Corn methyl ester	39,820	8.5	158	23
Soya bean oil biodiesel	39,760	4.3745	202.5	
Palm oil biodiesel	40,009	4.6889	214.5	10
Calophyllum inophyllum oil biodiesel	39,513	5.5377	-	10
Aphanamixis polystachya oil biodiesel	39,960	4.7177	188.5	10
Canola oil biodiesel	40.195	4.5281	186.5	10
UTOME	39,080	5.1	164	

In the above table the observation clears that the Calorific value of Rice bran oil (41,300 KJ/kg) and Palm oil

biodiesel (40,009 KJ/kg) is higher than other biodiesel. The UTOME Calorific value (38,080 KJ/kg) is nearer to Jatropha biodiesel (39,594 KJ/kg), Corn methyl ester (39,820 KJ/kg) and Calophyllum inophyllum oil biodiesel (39,513 KJ/kg). The flash point of Corn methyl ester is 158^{0}C which is higher than other biodiesel. The Palm oil biodiesel having214.5^{0}C which is higher than other biodiesel mentioned in the table. The UTOME having a flash point as164^{0}C, it is also higher than the Corn methyl ester (158^{0}C) and lower than the other biodiesel.

The Table 10 shows the properties of diesel and Karanja biodiesel at different blends and Table 11 shows the properties of UTOME and its blends.

Table 10: Properties of Diesel and Karanja Biodiesel in different Blends[24]

Fuel Type	Kinematic Viscosity (cSt)	Lower Heating Value (MJ/kg)	Flash Point (^{0}C)
Diesel	2.60	42.21	52
Karanja B100	9.60	36.12	187
Karanja B60	5.42	37.25	84
Karanja B40	4.63	37.85	81
Karanja B20	3.39	38.28	79

Table 11: Properties of UTOME at Different Blends

Fuel Type	Kinematic Viscosity (cSt)	Lower Heating Value (KJ/kg)	Flash Point (^{0}C)
UTOME	5.1	39080	164
B40	3.2	39423	60
B30	3.0	40231	58
B20	2.8	42881	54

The value of kinematic viscosity of UTOME blend B20 is 2.8 which is nearer to diesel 2.60 and lower than the Karanja biodiesel blend B20 which is 3.39. And UTOME having kinematic viscosity 5.1 which is less than the Karanja biodiesel is 9.60. The kinematic viscosity of UTOME blend 40 is 3.2 it is also less than the value of Karanja biodiesel bending 40 which is 4.63. The lower heating value of UTOME is 39080 KJ/kg which is more than the Karanja biodiesel 42.21 MJ/kg and the value of UTOME blend 20 is 42881 KJ/kg which is also higher than the Karanja B20 bend which is 38.28MJ/kg. The flash point of Karnja biodiesel (187^{0}C) is higher the UTOME (164^{0}C) and the flash point UTOME (54^{0}C) which is lower than the Karanja blend 20 (79^{0}C) and nearer to diesel (52^{0}C)

Engine Performance using other Biodiesels and Utome

In the below table 12, there are 27 literatures to study the effect of pure biodiesel on engine power and with a biodiesel engine (special with pure biodiesel) power will drop due to loss of heating value of biodiesel 70.4% of them agreed this.

Table 12: Statistics of Effects of Pure Biodiesel on Engine Performance and Emissions [25]

	Total no of References	Increase		Similar		Decrease	
		Number	%	Number	%	Number	%
Power Performance	27	2	7.4	6	22.2	19	70.4
PM emissions	73	7	9.6	2	2.7	64	87.7
NO_x	69	45	65.2	4	5.8	20	29.0
CO emissions	66	7	10.6	2	3.0	57	84.4
HC emissions	57	3	5.3	3	5.3	51	89.5
CO_2	13	6	46.2	2	15.4	5	38.5

Comparing with diesel neem biodiesel blents are showing higher brake thermal efficiency. There is no significant drop in engine performance in terms of brake power neem biodiesel can replace diesel in the form of blents [26]. CIME (Calophyllum Inophyllum Methyl Ester) biodiesel and it decrease with increase in percentage of biodiesel in blends comparing with this BTE (Brake Thermal Efficiency) is higher for biodiesel. With the increase in percentage of CIME biodiesel in theblends, the BSFC (Brake Specific Fuel Consumption) also increases [27]. The efficiency with B20 blend is higher as compared to B30 and diesel, BTE is of CI engine using NOME blendB20, B30and diesel are 28.32%, 27.69% and 26.74% respectively at full load condition [28]. The observation clear that under various loading conditions the SFC is higher for all WCME (Waste Cooking Oil Methyl Ester) and its blends than diesel. For diesel fuel SFC is 0.351 kg/Kw-h for WCME100 and is 0.275kg/Kw-h. The maximum BTE of diesel fuel is 30% and those of WCME100 is 26% it is because BTE of WCME and its blends is slightly lower than that of diesel fuel [29]. And also because of WCME's lower heating value, increased viscosity and higher density leads to poor atomization and fuel vaporization. Average values and % changes in BSFC are 0.264 kg/KWh, 0.275 kg/KWh, 0.287 kg/KWh and 0.302 kg/KWh of No-2 diesel, 20% SME, 40% SME and SME respectively. And BTE are 32.09 %, 31.25%, 30.5% and 29.5% of No-2 diesel, 20% SME, 40% SME and SME respectively. The brake thermal efficiency of No-2 diesel, 20% SME (Soybean methyl ester), 40% SME and SME are 32.09%, 31.25%, 30.5% and 29.5% are respectively. The BSFC of No-2 diesel, 20% SME, 40% SME and SME are 0.264 Kg/KW-h, 0.275 Kg/KW-h, 0.287 Kg/KW-h and 0.302 Kg/KW-h are respectively [30].

As the load increases in the JOME (Jatropha oil methyl ester) operation, there is a steady increase in efficiency. Compared to diesel fuel the BTE is 29 % with JOME and its lower and higher viscosity. This is because of the result of the low volatility, higher viscosity and density of the jatropha oil due to pour mixture formation [31]. The brake thermal efficiency of Karanja biodiesel, B20, B40, B60 and B80 are 22.71%, 26.79%, 26.19%, 24.26% and 23.96 % respectively [24].

The brake thermal efficiency of Jatropha, Mahuva, Neem, Jojoba and Karanja are 30.25%, 29.08%, 29.19%, 28.09% and 30.09% are respectively. The BSFC of Jatropha, Mahuva, Neem, Jojoba and Karanja are 0.2914 Kg/KW-h, 0.3102 Kg/KW-h, 0.3030 Kg/KW-h, 0.3164 Kg/KW-h and 0.2954 Kg/KW-h are respectively [32].

Single cylinder, water cooled, 4 stroke CI engine is as follows bore, 80 mm, stroke 40 mm, compression ratio 16.5:1, maximum power 3.7 KW. At different load and test fuel condition several performances and emission parameters have been evaluated. With variable load by changing the excitation of air cooled eddy current dynamometer the experiment has been extended out at constant 1500rpm, for a B20 blend of UTOME engine performance has been evaluated. The BTE of UTOME increases with the increase in load. At all loads the BTE of the fuels follows the same trend. At 180 bar pressure the BTE of D100 is 29%, B100 is 24%, B20 is 28%, B30 is 27% and B40 is 25%. The BTE decreases with the further increase of UTOME proportion in the blend, it may be because of the low value of heat, high density and viscosity of biodiesel.

The BSFC of UTOME decreases with the increase in load. At all loads BSFC of the fuels follow the same trend compared to diesel fuel. BSFC of UTOME biodiesel is slightly more. B20 blend has the lowest fuel consumption among all fuel blend. The BSFC at 180bar pressure the D100 is 0.32 kg/kW-h, B100 is 0.54 kg/kW-h, B20 is 0.48 kg/kW-h, B30 is 0.5 kg/kW-h and B40 is 0.52 kg/kW-h.

Engine Emissions using other Biodiesels and Utome

Air pollution can be reduced by using biodiesel. The use of biodiesel in a conventional diesel engine results in a substantial reduction of hydrocarbons, carbon monoxide, aromatic hydrocarbons, ketones, aldehydes, alkenes and particulate matter [33]. The emission characteristics of Jatropha oil blends in a direct injection, compression ignition engine were evaluated, the result clears that with an increasing proportion of Jatropha oil in the blends compared to diesel the emission parameters, such as smoke opacity, CO_2, CO and HC were increased [34]. For degummed Jatropha blend the C, CO_2, NOx and HC emissions are lower at high load compared to diesel. However the emission values at low loads almost parallel to diesel, because of higher ignition temperature and better combustion of Jatropha oil give less exhaust emissions than diesel [35-36]. The HC and PM are seen reduction with Calophyllumino phyllum biodiesel. However, there is slightly increased in CO and NOx and it is shown to reduce exhaust emission as compared to diesel [37]. The emissions of neem biodiesel CO, HC, CO_2 and NOx are decreasing and O_2 increasing than diesel [26]. The exhaust emissions CO and HC are decreased with neem oil biodiesel blends and NOx emission for B20 and B30are higher compared to diesel [28]. Waste cooking oil methyl ester emissions CO, UBHC and smoke emissions reduction for biodiesel and its blends compared to diesel and NOx emission marginally higher than diesel [29].

The CO (carbon monoxide) emission of pure diesel and UTOME blends at different loads it is observed that, for all the tested fuels and under all the loading conditions the CO emissions increases. Comparing to the UTOME, CO emission of diesel is more. At full load and at 180barpressure the CO of diesel is 0.074 %, B100 is 0.072%, B20 is 0.058%, and B30 is 0.064% and at B40 is 0.061%. The variation of HC (hydro carbon) emission of pure diesel and UTOME blends with different loads it is observed that for all the tested fuels under all loading conditions HC emissions increases. Due to the presence of higher hydrocarbon particles, the HC emissions are higher in the diesel for all the loading conditions. At full load and at 180bar pressure the HC of diesel is 36ppm, B100 is 32ppm, B20 is 24ppm, B30 is 29ppm and B40 is 28ppm.

The variation of NOx (Oxides of Nitrogen) emission of pure diesel fuel and UTOME of different blends with loads is observed that, with increasing load the amount of NO_x is increased. The NO_x emission of 180bar pressure diesel is 483ppm, B100 is 527ppm, B20 is 622ppm, B30 is 536ppm and at B40 is 598ppm. The smoke opacity emission of pure diesel and UTOME blends is observed that under all the loading conditions the smoke opacity increases with all tested fuels. Compared to diesel fuel smoke opacity is quietly lower for the biodiesel blends. The value of smoke opacity emission at 180bar pressure of diesel is 94%, at B100 is 76%, at B20 is 90%, at B30 is 86% and at B40 is 84%.

CONCLUSIONS

From the comparative study carried out the following are the conclusions:

- Used Temple Oil could be a potential raw material for the production of biodiesel.
- The properties were found well within the standard limits, values were close to other biodiesel.
- From the cost analysis, it could be concluded that the cost of UTOME is less as compared to diesel.
- The diesel engine could be operated satisfactorily using UTOME blends with diesel fuel without any engine hardware modifications.
- CO, HC, and NOx emissions of diesel engine powered with UTOME were comparable with other biodiesel.

Overall, it can be concluded that the abundantly available UTOME could replace the fossil diesel, besides its lower cost, use of it provides energy security to the nation and reduces the burden of foreign exchange on the country.

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